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NEW APPARATUS FOR DETERMINING BLOOD OXYGEN SATURATION -- FLOW OXIMETER OF THE PO-01 TYPE

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[Following is the translation of an article by L. F. Sochivko, G. L. Dernovskaya-Zelentsova, G. Sh. Vasadze, and N. I. Kochetygov in Patolog. Fiziol. i Eksper. Terapiya (Pathological Physiology and Experimental Therapy), Vol. IV, No. 1, 1960, pages 71-73.]

From the construction-technological bureau of "Biofizpribor" (head -- chief constructor, G. V. Rusakov) and from the chair of pathophysiology (director -- Professor I. R. Petrov, Corresponding Member of the Academy of Medical Sciences USSR) of the Military Medical Order of Lenin Academy imeni S. M. Kirov.

For an experimental study of the various pathological processes the elucidation of the dynamics in change of blood oxygen saturation is of great importance. The laboriousness of existing gasometric methods for determining blood oxygen saturation do not permit their extensive use and cannot detect rapid and brief changes in blood oxygenation.

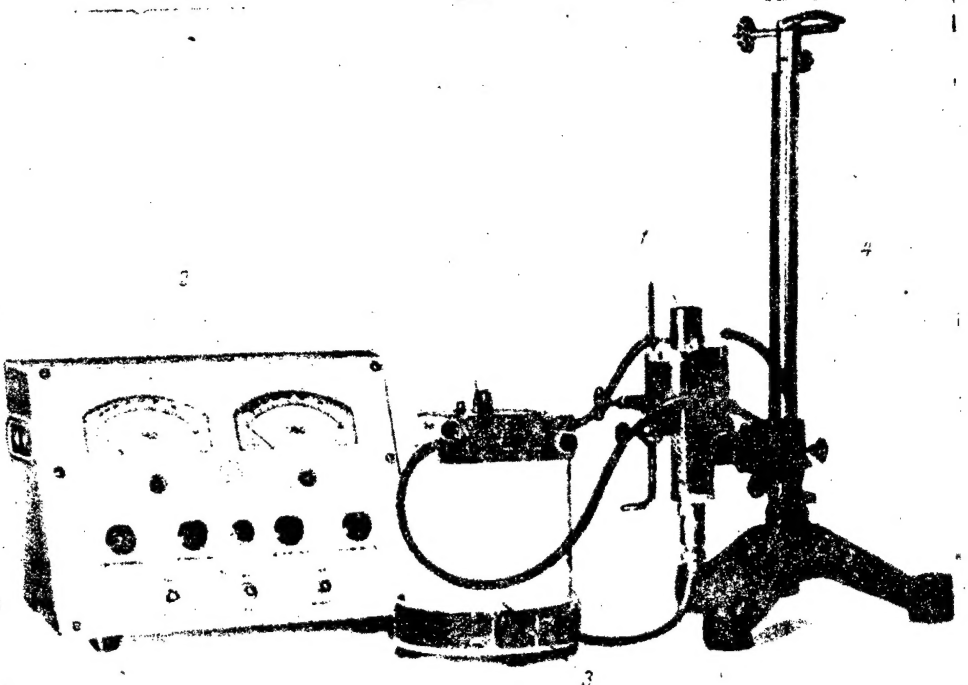
At the present time, Soviet medical industry is putting out the oxyhemograph O-36 and the oximeter O-38 (Krasnogvardeyets" plant) designed for investigating blood oxygen saturation in man. As is well known, the determination of the degree of blood oxygenation by means of these devices is based on a change in the quantity of light transmitted through the aural concha depending on the magnitude of blood oxygen saturation. However, our

attempts at utilizing the oximeter O-38 in experiments on animals were not crowned with success.

For certain experimental investigations the cuvette oximeters, such as the Brinkman hemoreflector produced by the Dutch company "Kipp" and the OKO-01 oximeter ("Biofizpribor" Construction-Technological Bureau), are suitable making it possible to determine the oxygenation of blood taken from blood vessels. However, the necessity for frequently taking blood in pathological processes with a rapid course limits the possibilities of using such devices. In connection with this, the need has arisen for an apparatus by means of which it might be possible to determine the degree of blood oxygen saturation directly in the large vessels at any time in the experiment. Such a device is the flow oximeter of the PO-01 type which has been created by the Construction-Technological Bureau of "Biofizpribor". Experimental research on animals during the course of creating this apparatus were carried out at the chair of pathophysiology of the Military Medical Order of Lenin Academy imeni S. M. Kirov.

Photometric methods for measuring blood oxygenation usually used in flow oximeters are based on the determination of the optic density of the sample investigated. In contrast to this, in the flow oximeter of the PO-01 type a measurement is made of the intensity of the light reflected by erythrocytes in a section of the spectrum near 650 millimum. In this portion of the spectrum the intensity of reflected light is a function of the degree of blood oxygenation and does not depend on the hemoglobin concentration. An indisputable advantage of the reflection method is the possibility of obtaining absolute values of oxygenation with measurements taken in the same portion of the spectrum.

The flow oximeter of the PO-01 type consists of a portable laboratory device made up of a feeler attached to an all-purpose stand, and amplifier (measuring 315 x 210 x x 225 centimeters and weighing seven kilograms) and a pump for creating a pulsating movement of venous blood through the cuvette of the feeler (see Figure).



Flow Oximeter of the PO-01 Type.
1 -- feeler; 2 -- amplifier;
3 -- pump; 4 -- all-purpose stand.

The feeler consists of a detachable measuring cuvette, a phototube, illuminator with a condenser and two standard glass reflectors for the purpose of setting up the scale of the device. The measuring cuvette is hooked up to a section of the animal's vascular system (artery, vein) by means of rubber tubes and cannulas. By means of a selenium phototube the intensity of light reflected by the blood passing through the cuvette is measured.

The phototube in combination with the incandescent light bulb makes it possible to carry out measurements without the application of a light filter. The phototube is hooked up to the input terminals of a balanced direct-current amplifier, which consists of 6-N15P triode with a pointer microammeter at the output terminals. The amplifier has two amplification channels, which makes it possible to carry out a simultaneous measurement of arterial and venous blood oxygenation.

The anode circuits of the 6-N15P tubes are fed by a

bridge rectifier which uses semiconductor germanium rectifiers. Voltage stabilization of the filament and anode circuits is accomplished by a ferro-resonance stabilizer.

Calibrating the scales of the apparatus, which is graduated in percentages of oxygenation, is accomplished by standard glass one of which corresponds to the reflection of completely reduced blood, and the other, to completely oxygenated blood. Such calibration and periodic checking of the scale of the apparatus are necessary for purposes of eliminating errors which may be introduced by possible changes in the parameters of the amplifier. During the calibration of the scale the standard reflectors are placed in turn over the phototube by means of a rotation of the appropriate indicators. In this process there is no need to remove the measuring cuvette from the feeler or to stop the flow of blood.

Application of the continuous-flow measuring cuvette, which is connected with part of the vascular system, for determining blood oxygenation creates the possibility for sedimentation of the erythrocytes on its walls. With an adequate rate of flow of the blood through the cuvette, which is observed in examination of arterial blood, sedimentation of the erythrocytes is insignificant and does not produce any noticeable distortions in the results of the measurement. However, in the determination of the venous blood oxygenation the erythrocytes settle on the walls of the cuvette in large quantities because of the slow rate of the blood flow. To avoid this the necessary rate of blood flow is achieved in the flow oximeter of the PO-01 type by connecting in a pump containing a modulator, which creates a pulsating movement of the blood in the measuring system.

For the purpose of preventing blood coagulation and the formation of clots in the cuvette and in the tubes connecting it with the vascular system the animal is given an intravenous injection of heparin.

The principal technical specifications of the device consists of the following. The flow oximeter of the PO-01 type is hooked up into an alternating current system having a voltage of 127-220 volts. The limits of measurement of the degree of blood oxygenation are from 30 to 100 percent. The basic error in measurement, according to the data of investigations on dogs, does not exceed ± four percent, with variations in the hemoglobin content not exceeding limits of 45 to 100 percent (according to the Sahli method), and in the absence of any essential pathological changes in

the blood which might affect its color (formation of methemoglobin, carboxyhemoglobin and others).

The oximeter scale is graduated with respect to dogs' blood. For the purpose of using the apparatus on other experimental animals it should be calibrated again.

The accuracy of the PO-01 oximeter was checked by means of comparing its readings with data obtained by means of the cuvette hemoreflector of Brinkman. In its turn, the reliability of Brinkman's hemoreflector readings was checked by a van Slyke apparatus. Here, it was shown that the average differences between the data which we obtained amounted to ± 1.5 percent. Tests of the type PO-01 oximeter were made both by means of the creation of an artificial blood stream with different degrees of oxygenation through the cuvette of the device and in experiments on dogs in which changes in blood oxygen saturation had been produced by various methods (inhalation of pure oxygen, carbon dioxide, asphyxia, blood loss, traumatic shock). In the Table the results are given for one of the experiments in which the blood oxygen saturation of the femoral artery was measured with the animal in different conditions (dog). Here, the average differences between the data of measurement of the degree of oxygenation obtained by means of the flow oximeter and the Brinkman hemoreflector amount to 2.5 percent.

Changes in Arterial Blood Oxygenation Determined by Means of the Flow Oximeter Type PO-01 and the Brinkman Hemoreflector

	Blood oxygen saturation (in %)		Difference in readings (in %)
	oximeter PO-01	Brinkman hemo-reflector	
Respiration of oxygen	100	98	2
	100	97	3
Respiration of air	96	92	3
	94,5	92	2,5
	94	92	2
	92	92	0
	88	92	4
Asphyxia	84,2	83	1,2
	82,5	80	2,5
	75	69	6
	73	69	4
	67	67	0
	58	58	0
	60	55	5
Mean differences			2,5

The flow oximeter of the PO-01 type indicates with sufficient accuracy the fast and ephemeral changes in the degree of blood oxygen saturation and can be used in experiments associated with the study of various pathological processes accompanied by disturbances in blood oxygenation.

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